IMPROVEMENT OF CLASSIFICATION ACCURACY WITH CONSIDERATION OF THE MIXTURE OF LAND COVERS

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Commission VII/4

ABSTRACT

Several trials have been made to measure tree cover ratio in urban areas through classification of land covers with satellite images, such as Landsat TM data. In the trials a maximum likelihood method (MLM) has been usually applied. However, the trials have not always given satisfactory results in terms of measurement accuracy. Because an ordinal maximum likelihood method doses not allow resolving the percentage of tree cover within an IFOV, though in urban areas many of tree covered areas are too small to occupy a whole IFOV, but too large to be ignored for the measuring purpose. Authors proposed a MLM with consideration of the mixiture of land covers and applied it to measuring tree cover ratio in urban areas with a Landsat TM data. The MLM with consideration of the mixture requires no training sets for mixed land cover classes. In terms of measurement accuracy, the results of three test cases showed that the MLM with consideration of the mixture gave better result (1.7% in RMSE) than an ordinal MLM.

INTRODUCTION

Vegetation cover ratio or tree cover ratio is often used as one of the most important indicator of urban environments. Tree cover ratio has been usually measured manually with color aerial photographs. However, manual photo-interpretation and measurement of tree area require much labor and time, and that has prevented from measuring tree cover ratio in many urban areas.

Satellite image data, such as Landsat TM data, though their ground resolutions are much inferior to aerial photographs, includes multispectral information of land covers in much larger areas. Some trials have been made to measure tree cover ratio through classification of land covers with satellite image data, in which a maximum likelihood method (MLM) has been usually employed. However, those trials have not always given satisfactory results in terms of mea surement accuracy.

In urban area, especially in Japan, lands are densely utilized and many small tree covered areas are scatteread in 'non-tree' area. Each tree covered area is too small to occupy a whole IFOV of satellite image and to be classified as 'tree', but too large to be ignored in measuring tree cover ratio for assessing urban environment. An ordinal MLM does not allow resolving the percentage of tree cover within IFOV of satellite images, and fails to pick up pixels in which the percentage of tree cover is relatively low. This constraint would be thought to cause serious errors in measuring tree cover ratio in urban areas.

Authors proposed an MLM with the consideration of the mixture of land covers and applied it to measuring tree cover ratio in urban areas. Three test cases were examined for assessing the performance of the MLM with the consideration of the mixture in comparison with an ordinal MLM.

PREVIOUS STUDIES

There exist two main groups concerning methods of resolving the mixture of land covers. One group consists of the methods based on linear regression models which relate the percentage of a object-land cover to the combination of reflectance values in several bands and/or some kinds of indices, such as Vegetation Index, obtained from reflectance values. However, building linear regression models requires pixels in which the proportion of an object-land cover is exactly determined. Acquisition of the proportion data in each pixel is encumbered in practical applications because it is not easy to determine accurately the exact locations of the mixed pixels.

The other group is based on a general weighted average equation. Under the assumption that mean reflectance vector of a mixed pixel nearly equals the weighted average of component class mean vectors, the proportion of each component is given as a solution of a weighted average equation. However, it is necessary that two important constraints should be observed [3] :

(1) no (pure) component class mean vector in a mixture must be similar to a weighted average of the other component class mean vectors.

(2) in case the number of spectral bands available is less than the number of components, estimation accuracy of the proportion is poor.

An approximate MLM [1] would be thought of an extension of an ordinal MLM. The method yields the proportion of a component through calculating the differences of Mahalanobis distances between a mixed pixel and each component class of the mixture. The method proved promising in five test cases for geological applications.

A CLASSIFICATION METHOD WITH CONSIDERATION OF THE MIXTURE

Figure 1 shows a classification procedure with consideration of the mixture of land covers. The procedure is based on MLM. MLM is widely used in image classification and many image processing systems provide programs of MLM.

At the first stage of the procedure, some of pixels of pure components are extracted for training sets. At the same time, mean vecters and covariance matrices of mixed classes are estimated through weighted average of mean vectors and covariance matrices of pure component classes. The weight values are proportional to the percentages of pure components. The stepwise proportion of mixture are given for mixed classes. Step width is determined with the consideration of degree of spectral separation between pure classes. Both extraction of only pure pixels and estimation of mean vectors and covariance matrices of mixed classes are not unencumbered because the exact locations of only pure component pixels must be determined and the standard of pixel extraction for pure pixels is clear. The first classification with MLM is

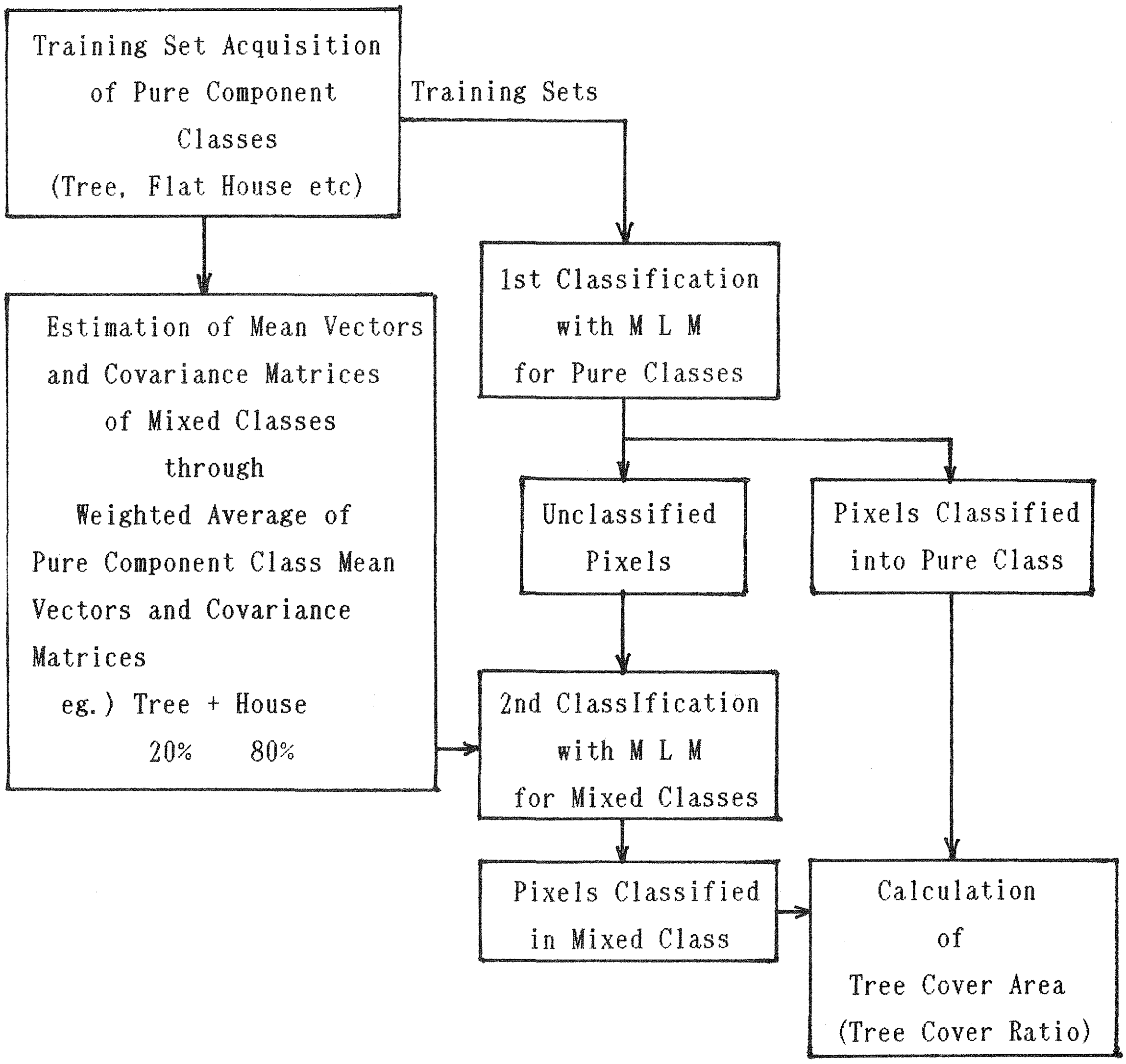

Fig. 1 MLM Based Classification Procedure With
Consideration of the Mixture of Land Covers
(MLM: Maximum Likelihood Method)

carried out for only pure classes. In the first classification there exists a threshold of Mahalanobis distance between reflectance vector of an object-pixel and the nearest pure component class mean vector. A pixel whose minimum Mahalanobis distance is larger than the threshold remains unclassified. In test cases, authors assumed the threshold to be 2σ.

At the second stage, pixels remained unclassified at the first stage are classified into mixed classes. Total amount of the percentage of tree cover of each pixel yields tree cover area.

Under the assumption that mixed class mean vectors equal the weighted average of pure component class mean vectors, there exists serious problem that discrimination is difficult in case mean vector of a mixed class happen to come close to mean vector of any other class. Authors assume that there exist much more pixels of pure classes than pixels of mixed classes, and attach priority to pure classes in classification. The two-step classification algorithm reflects this assumption in a simplified form.

COMPARISON OF CLASSIFICATION ACCURACY

For the comparison of classification accuracy, three test cases were developed. Two of test areas, Honmoku (1) and Honmoku (2), are located near Yokohama Port, about 30km distant from the center of Tokyo. Both Honmoku (1) and (2) include large residential area with small tree covered areas scattered. The other test area, Kohoku New Town (NT) is located about 20km distant from the center of Tokyo. The area consists of tree areas, residential areas and barelands. Each of three test areas is about 750m×750m in size, and is divided into 625 (25×25) cells which is 30m×30m in size. Actual tree cover ratio of each test area was obtained through manual interpretation of color aerial photographs. Photo 1, 2 and 3 show actual tree cover ratio of 625 cells in each test area respectively.

The tree cover ratio obtained through classification of a Landsat TM data (July,23,1987) with the MLM with consideration of the mixture are shown in Photo 4, 5 and 6. The 625 cells were classified into pure and mixed classes shown in Table 1. For the comparison, tree cover ratios obtained with an ordinal MLM are shown in Photo 7, 8 and 9. A classification with an ordinal MLM corresponds to the first stage classification in Figure 1 with 3σ threshold of

	Actual Tree Cover	MLM with Consideration of Mixture	Ordinal MLM (threshold ;3σ)

Honmoku.1

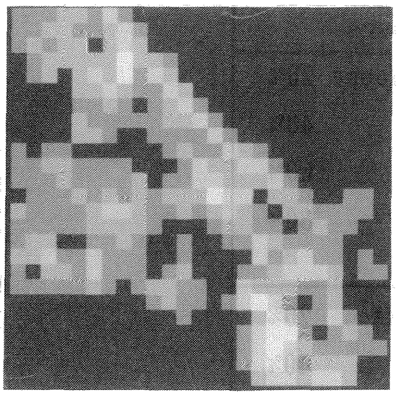

Photo 1

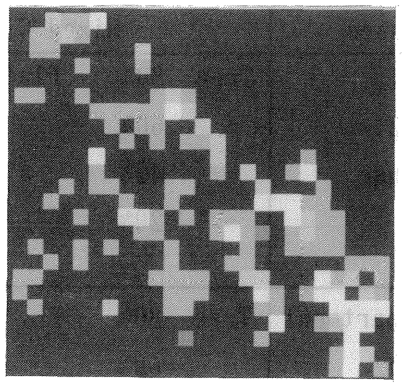

Photo 4

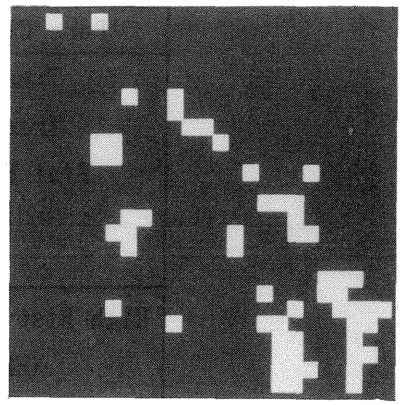

Photo 7

Honmoku.2

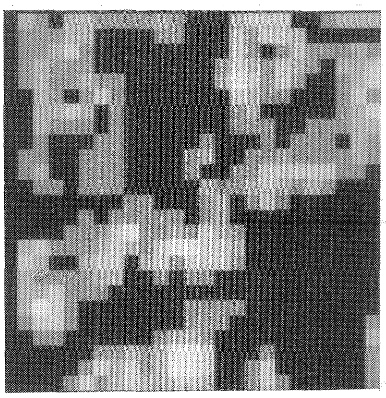

Photo 2

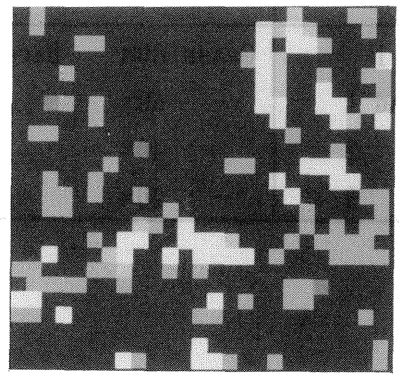

Photo 5

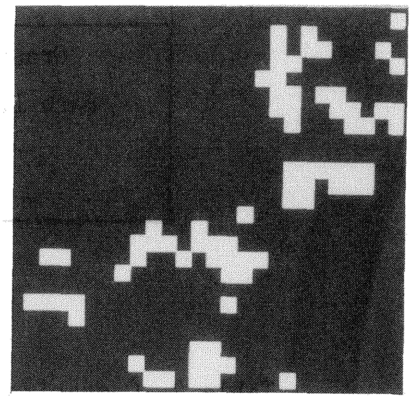

Photo 8

Kohoku.NT

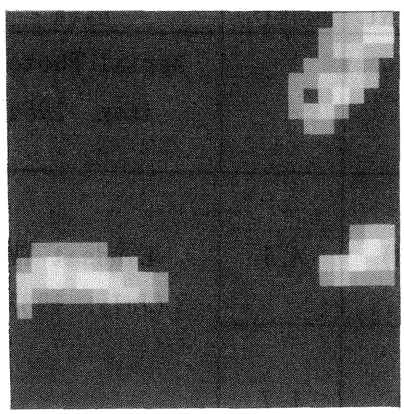

Photo 3

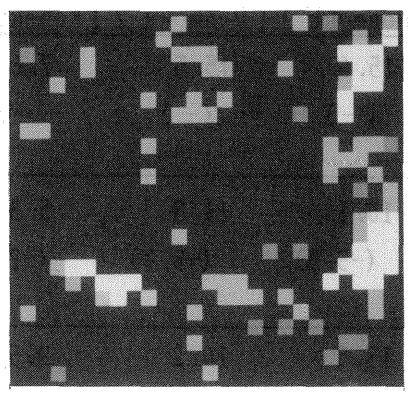

Photo 6

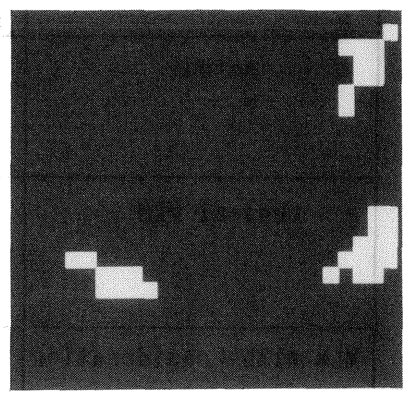

Photo 9

Photo 1～9 Comparison of Measurement Accuracy of Tree Cover Ratio

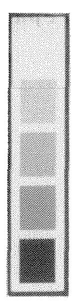

Table. 1 Pure and Mixed Land Cover Classes for Test Cases

Pure Classes	Mixed Classes			
Tree 1	Tree	80%	Flat House	20%
Tree 2	-	60%	-	40%
Flat House	-	40%	-	60%
	-	20%	-	80%
High Rise Apartment (HRA)	Tree	80%	HRA	20%
	-	60%	-	40%
	-	40%	-	60%
	-	20%	-	80%
Grass 1	Grass	80%	Bare Land	20%
Bare Land 1	-	60%	-	40%
- 2	-	40%	-	60%
- 3	-	20%	-	80%

Table. 2 Comparison of Measurement Accuracy of Tree Cover Ratio

Case	Tree Cover ratio of Test area (%)			RMSE (%)	Data
	Honmoku 1	Honmoku 2	Kohoku Nt		
Actual	15.6 (-)	15.5 (-)	7.6 (-)	-	Aerial Photos (Aug. 1984)
Ordinal MLM	10.1 (-5.5)	11.8 (-3.7)	5.3 (-2.3)	4.1	Landsat TM (July. 1987)
MLM with Consideration of the Mixture	13.5 (-2.1)	16.2 (0.7)	9.5 (1.9)	1.7	

(Discrepancies (MLMs - Actual) are within parentheses) minimum Mahalanobis distance. The results with an ordinal MLM (Photo 7～9) show that many of pixels in which tree cover ratios are relatively low are classified into non-tree classes.

Table 2 shows tree cover ratio of each test area. In every case, tree cover ratio obtained with the MLM with consideration of the mixture comes closer to actual ratio than that with an ordinal MLM. Measurement accuracy with the MLM with consideration of the mixture is 1.7% in RMSE, while accuracy with an ordinal MLM is 4.1% in RMSE. In these test cases, an ordinal MLM has tendency of underestimation because a MLM failed to pick up pixels in which tree cover ratio is relatively low.

CONCLUSIONS

(1) A classification method with consideration of the mixture of land covers was developed. The results of three test cases showed the measurement accuracy of tree cover ratio with the classification method with consideration of the mixture is 1.7% in RMSE, which is better than that with an ordinal MLM in every case.

(2) The classification method with consideration of the mixture is based on MLM, and requires no training sets for mixed land cover classes. These mean that the classification method with consideration of the mixture does not require much more time and labor than an ordinal MLM does in practical applications.

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